# SELECTIVE SENSITIVITY OF SCHEDULE-INDUCED ACTIVITY TO AN OPERANT SUPPRESSION CONTINGENCY

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The sensitivity of pigeons' schedule-induced activity to operant consequences was studied in two experiments. During a 30-s interval between food presentations, a keylight stimulus brightened incrementally. Stable terminal key pecking and interim locomotor activity developed. An operant "setback" contingency was applied to activity. The contingency arranged for locomotor movements (detected by a nine-panel floorboard) to be followed by a resetting of the keylight brightness to a dimmer value and a 1-s delay of reinforcement (for individual responses). Experiment 1 showed that activity patterns were highly sensitive to their operant consequences. Accompanying key-peck rates were only transiently affected. In Experiment 2, the setback contingency was imposed during restricted portions of the trial, and differential operant control of activity was demonstrated. However, birds in this study produced higher rates of key pecking as activity rates were reduced. These results suggest that although schedule-induced activity arises in response to the temporal arrangement of stimulus events, this behavior may retain considerable sensitivity to response–consequence relations.

*Key words:* schedule-induced activity, autoshaping, omission training, negative automaintenance, serial stimuli, operant–respondent interactions, pigeons

The multiplicity of forms of schedule-induced behavior has led to several efforts to sort them into meaningful categories. Staddon and Simmelhag (1971) separated these behavior patterns into "interim" and "terminal" types on the basis of their distribution in the inter-reinforcement interval (IRI); interim behavior occurs early in the IRI, and terminal behavior occurs near the end of the IRI. These patterns are also alleged to be distinctive in form, in that terminal behavior frequently bears a similarity to the consummatory behavior associated with the reinforcer (e.g., Jenkins & Moore, 1973), whereas interim behavior has more diverse forms but in general is not oriented to the source of the food (Staddon, 1977).

Of the two classes of behavior, terminal behavior is certainly the better understood, in part because the characteristics of terminal behavior seem to closely match those of Pavlovian conditioned responses (Staddon, 1977). They appear to arise in response to signals of an upcoming reinforcer, and are sensitive to parameters of the Pavlovian pairing operation in much the same way as traditional reflexive conditioned responses are.

Interim behavior, on the other hand, is not so well understood. There are many instances of schedule-induced behavior that seem to fit the interim definition. These include adjunctive behavior (Falk, 1971), schedule-induced aggression (Cole & Litchfield, 1969), and schedule-induced activity in pigeons (Killeen, 1975) and rats (Levitsky & Collier, 1968), to name a few. Despite the number of observations that qualify under the definition of interim behavior, there is little consensus on the parameters that control the ongoing frequency of the behavior.

For example, one question that has been raised with respect to both interim and terminal behavior concerns the extent to which the frequency of these responses might be modified by operant contingencies. Autoshaped terminal behavior was originally suspected to be relatively insensitive to operant contingencies imposed upon it. Omission-training tests (e.g., Williams & Williams, 1969) failed to show significant reduction of autoshaped responses when responses during a keylight conditioned stimulus (CS) canceled the next scheduled reinforcer. However, subsequent modifications of this procedure have quite ef-

fectively reduced autoshaped behavior (Allan & Matthews, 1991; Barrera, 1974).

Similarly discrepant observations have been made with regard to schedule-induced polydipsia, another type of interim behavior. Although some procedures have suggested weak sensitivity of this behavior to its consequences (Falk, 1964; Flory & Lickfett, 1974; Hawkins, Schrot, Githens, & Everett, 1972; Moran & Rudolph, 1980; Segal & Oden, 1969), other work has shown good contingent control of response rates by both delay of reinforcement (Pellon & Blackman, 1987) and punishment (Bond, Blackman, & Scruton, 1973).

Caution should be taken in generalizing from these results for schedule-induced polydipsia to other types of interim behavior, such as schedule-induced activity, which has been demonstrated to be functionally distinct from polydipsia in several respects. Activity responses tend to occur later in the IRI than drinking (Matthews, Bordi, & Depollo, 1990), and activity occurs profusely on random-interval schedules, whereas adjunctive drinking is quite restricted on these schedules (Plonsky, Driscoll, Warren, & Rosellini, 1984). Accordingly, the sensitivity of schedule-induced activity to an operant contingency may be at variance with the findings of schedule-induced polydipsia.

The first question to be addressed by the present experiments concerns the sensitivity of schedule-induced activity to a "setback" procedure—an operant contingency known to decrease effectively the frequency of terminal behavior (Allan & Matthews, 1991). The same operant contingency was used to observe interactions between the target behavior and other behavior forms present in the test situation. Other experiments have indicated that there may be a competitive trading relation between schedule-induced activity and terminal key pecking. Bordi and Matthews (1990) have shown that tranquilizing drugs decrease schedule-induced activity and simultaneously increase terminal pecking. Similarly, Matthews et al. (1990) have shown that reducing the level of change between serial stimuli signaling the passage of time within the IRI (an added clock; Ferster & Skinner, 1957) decreases activity and increases terminal pecking. These results reinforce the notion of a competitive relationship between activity and key pecking such that operations that enhance one

diminish the other (Staddon, 1977). On the other hand, Allan and Matthews (1991) reported a seemingly contrary result. While measuring both schedule-induced activity and autoshaped key pecking, they applied a setback contingency to key pecking alone. Although strong reduction of key pecking developed quickly, no systematic effects on activity were observed. This failure of activity rates to change as key-pecking frequency decreased suggests that the two behavior classes do not necessarily have a competitive relationship.

One possible interpretation of this apparent absence of competition between activity and key pecking is that the competition is not symmetric; that is, key pecking may replace activity but activity does not replace pecking. By this account, the drugs in the Bordi and Matthews study (1990) and the decreased range over which stimuli changed in the Matthews et al. (1990) study decreased activity directly. This decrease, in turn, led to an increase in key pecking. In the Allan and Matthews (1991) experiment, however, key pecking was decreased directly and was accompanied by no systematic increase in activity. The obvious experimental test of this notion is to apply selectively the Allan and Matthews (1991) setback contingency to activity. The asymmetric competition notion will be disconfirmed if the contingent reduction of activity fails to yield an increase in key pecking.

## EXPERIMENT 1

The first experiment utilized a setback contingency (Allan & Matthews, 1991) imposed upon a baseline of schedule-induced behavior that included interim activity and autoshaped key pecking (Matthews & Lerer, 1987). In this procedure, 3-s food deliveries were presented every 30 s and were signaled by a keylight that brightened continuously throughout the IRI. Locomotor activity was automatically detected by a segmented floorboard, and key pecks were detected by a transilluminated key switch. Activity peaked just before the midpoint of the IRI, and key pecking was initiated near the midpoint and continued until food was delivered. After a period of response stabilization a contingency, consisting of a setback of the increasing-intensity stimulus value to a previous value, followed activity responses. Because the reinforcer did not occur until the

brightest value was reached, a brief delay of reinforcement was added for each response. The experiment addressed two questions; the first concerns the sensitivity of schedule-induced activity to an operant contingency, and the second concerns an analysis of the interactions among classes of schedule-induced behavior (activity and key pecking).

## METHOD

### Subjects

Four naive male White Carneau pigeons were maintained at 80% of their free-feeding weights. Water was constantly available in individual home cages.

### Apparatus

The experimental chamber measured 73 cm long, 38 cm wide, and 41 cm high, and housed a Grason-Stadler pigeon intelligence panel and a nine-panel floorboard system (49 cm long by 38 cm wide) positioned in front of the response panel. The intelligence panel was equipped with a keylight positioned 20.5 cm above the floor of the chamber and was centered above a food aperture (4.5 cm by 5 cm). The food delivery opening was 7 cm from the floor of the chamber. Both keylight and hopper aperture were centered horizontally on the intelligence panel.

The keylight stimulus was produced by five yellow light-emitting diode bars (Hewlett-Packard HLMP-2450), forming a 1.9-cm square, which were mounted behind the 2-cm response key. Apparent stimulus intensity was varied using a pulse-width modulation technique. A Plessey Micro-I® computer generated a 60-Hz train of pulses that varied in duration from 0 to nearly 17 ms. Using 30 values derived from an increasing logarithmic function of pulse widths and assigning one value to each second of the 30-s trial allowed the presentation of a stimulus light that appeared brighter as each second of the trial interval elapsed. The computer controlled all the experimental events and recorded key pecking and locomotor activity on the floorboard (see below).

The floor of the test chamber consisted of a vinyl-covered floorboard segmented into nine pressure-sensitive panels. The acrylic panels (16.2 cm by 12.1 cm by 0.3 cm) rested on four microswitches (Honeywell V31-131-D8), with one switch positioned under each corner of the panel. Each panel was held in position by two machine screws going through the panel and into an acrylic support running lengthwise underneath the floorboard. The microswitches under each panel were wired in parallel so that when a bird stepped anywhere on the panel, closing at least one of the microswitches, onset and offset times were recorded by the computer.

The top of the chamber was made of transparent acrylic that permitted video monitoring of subjects. The chamber was housed in an Industrial Acoustics sound-attenuating chamber that was illuminated by a 60-W lamp mounted 1 m above the chamber. The computer, interfacing, and video monitoring equipment were located in a room adjacent to the sound-attenuating chamber.

### Procedure

Subjects were hopper trained by scattering a small amount of grain in front of the hopper before a training session was initiated. When the subjects began eating the scattered grain, a 40-trial training session was started, during which the hopper was raised for 3 s on a variable-time (VT) 30-s schedule. All subjects began eating from the hopper by the second training session.

*Phase 1.* For 15 days all birds were exposed to a fixed-time (FT) 30-s schedule with the added increasing-brightness clock stimulus (Figure 1A). Each FT interval began with the presentation of the lowest intensity keylight stimulus followed by the remaining stimulus-intensity values, with stimulus-value changes occurring each second of the interval. The highest intensity stimulus was followed by a 3-s food delivery. A trial was therefore defined as the presentation of the stimulus sequence followed by the food delivery, and each session consisted of the presentation of 40 trials of this type. During these baseline sessions, neither key pecking nor panel closures had any effect on trial duration (see Matthews & Lerer, 1987).

*Phase 2.* On Days 16 through 35, a delay-of-reinforcement (setback) contingency for panel closures was imposed. Each activity response (panel closure) during the trial caused a stimulus setback that consisted of an immediate change in the keylight brightness to the previous value in the brightness series. Be-
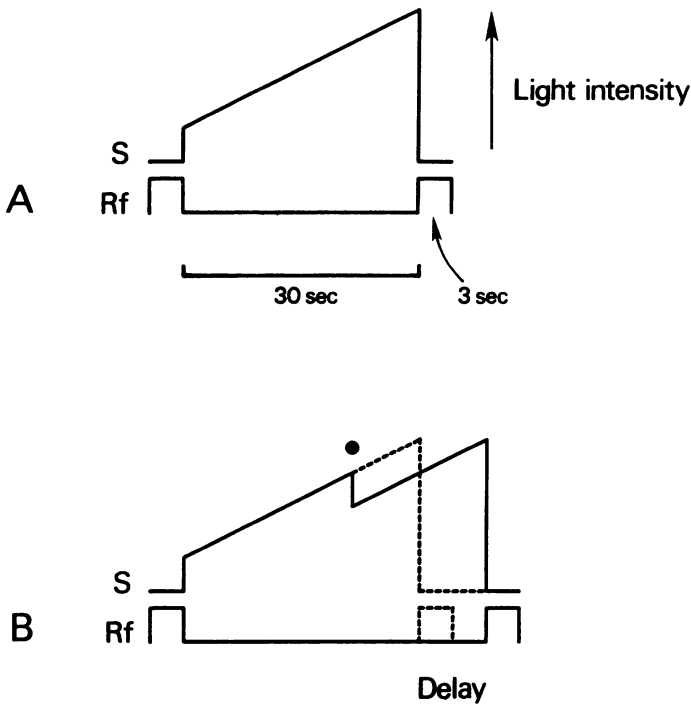
Fig. 1.   Schedule diagrams portraying (A) changes in light intensity during IRIs with no contingencies, and (B) an example of how light-intensity changes and food deliveries are delayed during the setback contingency, with the filled circle indicating the temporal location of a bout of activity responses. The dashed line portrays the light-intensity changes that would occur in the absence of the bout of responding.

cause the reinforcer was not presented until the stimulus ramp reached its highest value, each setback had the additional effect of delaying the reinforcer for 1 s (Figure 1B). Although each panel closure delayed the reinforcer for 1 s, the keylight brightness did not decrease below the initial value presented at the beginning of the trial. Each response that occurred during the dimmest value held the keylight at that value for an additional second. Only after 1 s without a floor-panel response did the intensity of the keylight again increase. Phase 2 sessions also consisted of 40 trials each.

*Phase 3.* The pigeons were returned to the Phase 1 conditions for 5 days. During these sessions, neither key pecks nor panel closures had any effect on trial duration.

## RESULTS

The mean activity and key-pecking rates (responses per second) per session are shown for individual subjects in Figure 2. Each panel shows the data from the last five sessions of Phase 1 and all of Phases 2 and 3. The activity rates for all 4 subjects decreased conspicuously in the first session of the setback contingency. Activity levels remained reduced to consistent levels throughout Phase 2 for all subjects. In Phase 3, activity responding for all 4 subjects recovered by the third session, with rates matching or exceeding Phase 1 levels.

Overall, the setback contingency produced immediate and stable decreases in activity levels but did not result in the complete elimination of the response. All birds continued to move at a rate of about six panel closures per trial throughout the setback phase.

In contrast, key-pecking rates were not systematically affected by the setback contingency, although 3 of the 4 birds showed transient increases in key-pecking rates. Bird 18's rate of pecking remained fairly stable, although an increase in rate was observed during Sessions 26 and 27. Subject 19 produced higher rates from Sessions 26 to 33, after which pecking frequency decreased. Key pecking for Subject 24 increased slightly after introduction of the setback contingency but remained stable through Phase 3. Subject 25's key-pecking rates increased dramatically on the first day of the
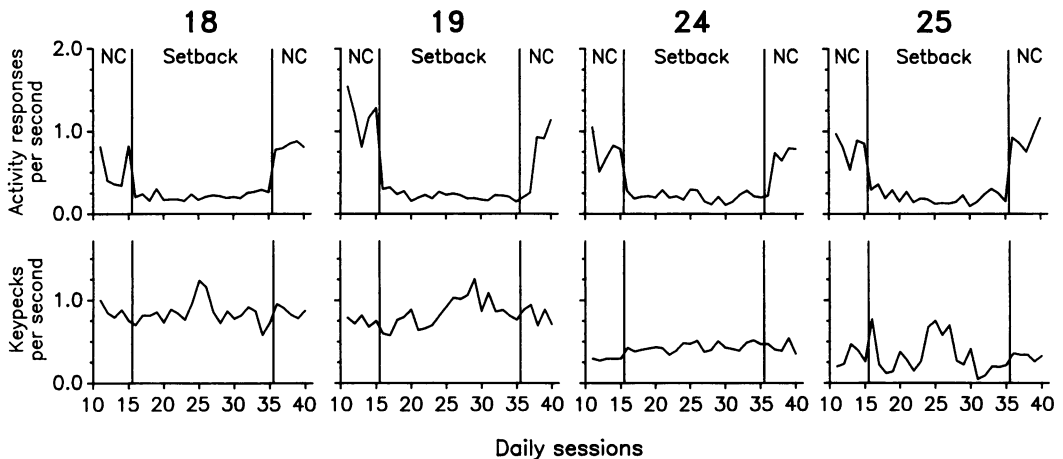
Fig. 2. Each panel depicts individual-subject mean response rates (per second) as a function of daily sessions. In each panel, vertical lines divide the no-contingency (NC) phases from the setback phase. Bird numbers are indicated along the top. Individual activity rates are represented along the upper row of panels, and key-pecking rates are depicted along the lower row.

setback contingency but then dropped to low levels until Session 24. From Sessions 24 to 27, key-pecking rates remained relatively high, after which decreased rates of responding were observed through Phase 3. However, for none of the birds was there any systematic change in pecking rate over the 20 sessions that might be tied to corresponding changes in activity levels.

## DISCUSSION

The present finding that schedule-induced activity is sensitive to its consequences confirms previous work demonstrating that autoshaped key pecking is similarly reduced in frequency as a function of the imposition of the setback contingency (Allan & Matthews, 1991). Analysis of the present results suggests that (a) the contingency abruptly and thoroughly reduced the frequency of locomotor behavior, (b) activity rates increased when the contingency was removed, and (c) the effect of the contingency was selective in that only the target response was consistently reduced; key pecking was not systematically altered during the contingent conditions.

Before concluding that schedule-induced activity is sensitive to its consequences, another interpretation of these data might be considered. The decrease in responding may have resulted from the decrease in density and/or pattern of reinforcement produced by the contingency. Two points argue strongly against

this view. First, if activity were not sensitive to its consequences and if the observed decrease was due simply to alterations in the stimulus sequence, what explanation might be offered for continued activity reduction even after the stimulus sequence and density of reinforcement returned, essentially, to their original values? It is clear from the reduced rates of activity depicted in Figure 2 that average trial times increased only to approximately 35 to 36 s from the 30-s interval that would have occurred in the absence of activity responses. In addition, if the effect of the activity contingency was simply to eliminate the regular, periodic nature of reinforcer delivery, hence producing a "random-time" schedule, then previous research predicts an increase in activity rates (see Matthews et al., 1990). In fact, all of the low activity levels produced by the setback procedure were well below those required to allow reinforcers to occur fairly regularly (every 35 s instead of every 30 s), suggesting that the contingency exerted direct control over the frequency of responding.

Second, the effects of the procedure were highly selective; there was a strong effect on activity but no systematic effect on key pecking. These results mirror the results of the Allan and Matthews (1991) study, in which key-peck frequency was reduced while activity rates remained relatively unaffected. If reinforcer density alone is the source of the response reduction, then both activity and key pecking

should be affected similarly when reinforcement density is manipulated (cf. Staddon, 1977, p. 128). Further experimental work might profitably employ a yoked-control group exposed to the changes in density of reinforcement produced by the setback group. However, even without the yoked control, the highly selective character of the setback contingency discourages the view that changes in density of reinforcement alone are sufficient to produce the decrease in observed activity.

The consistency of the effects of the setback contingency across behavior types suggests that the strength of operant contingencies may not be dependent upon the form of the target response. However, although activity in general was selectively reduced in Experiment 1, the contingently affected behavior is not necessarily unitary in character. It may be the case, for example, that initial movement responses (interim behavior) are produced by the removal of the reinforcer (a postreinforcement effect), with subsequent locomotor behavior being an increasing function of time to the next reinforcer (terminal behavior). Indeed, if different types of behavior early and late in the IRI are functionally distinct forms of schedule-induced behavior, they may also be differentially sensitive to imposed consequences. In Experiment 2, the setback contingency was selectively imposed upon schedule-induced activity as it occurred in different portions of the IRI.

## EXPERIMENT 2

Schedule-induced activity may involve different kinds of behavior. Matthews and Lerer (1987) have distinguished "retreat" activity that occurs early in the IRI and "pacing" activity that occurs toward the middle of the IRI (see also facultative behavior; Staddon, 1977, p. 135). Further, activity late in the IRI may be terminal in character (Staddon & Simmelhag, 1971). Experiment 2 was designed to determine whether these putative behavior classes may be distinguished by their differential sensitivity to an explicit operant contingency (setback). The setback contingency was imposed selectively on behavior occurring within three segments of the IRI. The IRI was divided into three segments so that the setback contingency could be used to test the sensitivity of locomotor behavior in each segment. Separate groups of

pigeons were exposed to the setback contingency for schedule-induced activity in each of the three segments.

## METHOD

### Subjects and Apparatus

Twelve naive male White Carneau pigeons were maintained at 80% of their free-feeding weights. All other conditions, including the experimental chamber and recording equipment, were identical to those in Experiment 1.

### Procedure

All subjects were initially hopper trained using the same procedure employed in Experiment 1.

*Phase 1.* In this phase, all birds were exposed to an FT 30-s schedule with the increasing-intensity keylight stimulus. Each session consisted of 40 trials, and the entire phase lasted for 15 days. This procedure was identical to Phase 1 of Experiment 1.

*Phase 2.* The 12 subjects were divided into three groups of 4 birds each. Each group was exposed for 15 days to one of three experimental treatments (described in Figure 3). Each treatment consisted of the imposition of the setback contingency during a selected portion of the IRI.

The duration of each trial segment was based on the intratrial distributions of activity during Phase 1, an example of which is shown in Figure 3A. The boundaries were the same for all subjects in a group and were set so that retreat, interim pacing, and terminal pacing would be sampled (see Matthews & Lerer, 1987). Figure 3B shows that for Group 1, the setback contingency was imposed for panel closures that occurred during brightness values associated, in Phase 1, with the first 7 s of the trial (when retreat tended to occur). The corresponding postsetback response-independent period covered the final 23 s of the IRI.

For Group 2, the setback was contingent on panel closures that occurred between the 8th and 17th seconds of the trial (when interim pacing was most probable). The presetback and postsetback segments were 7 s and 13 s in duration, respectively.

For Group 3, the setback contingency was imposed for panel closures that occurred during intensities presented during the last 13 s of Phase 1 trials (a period during which ter-
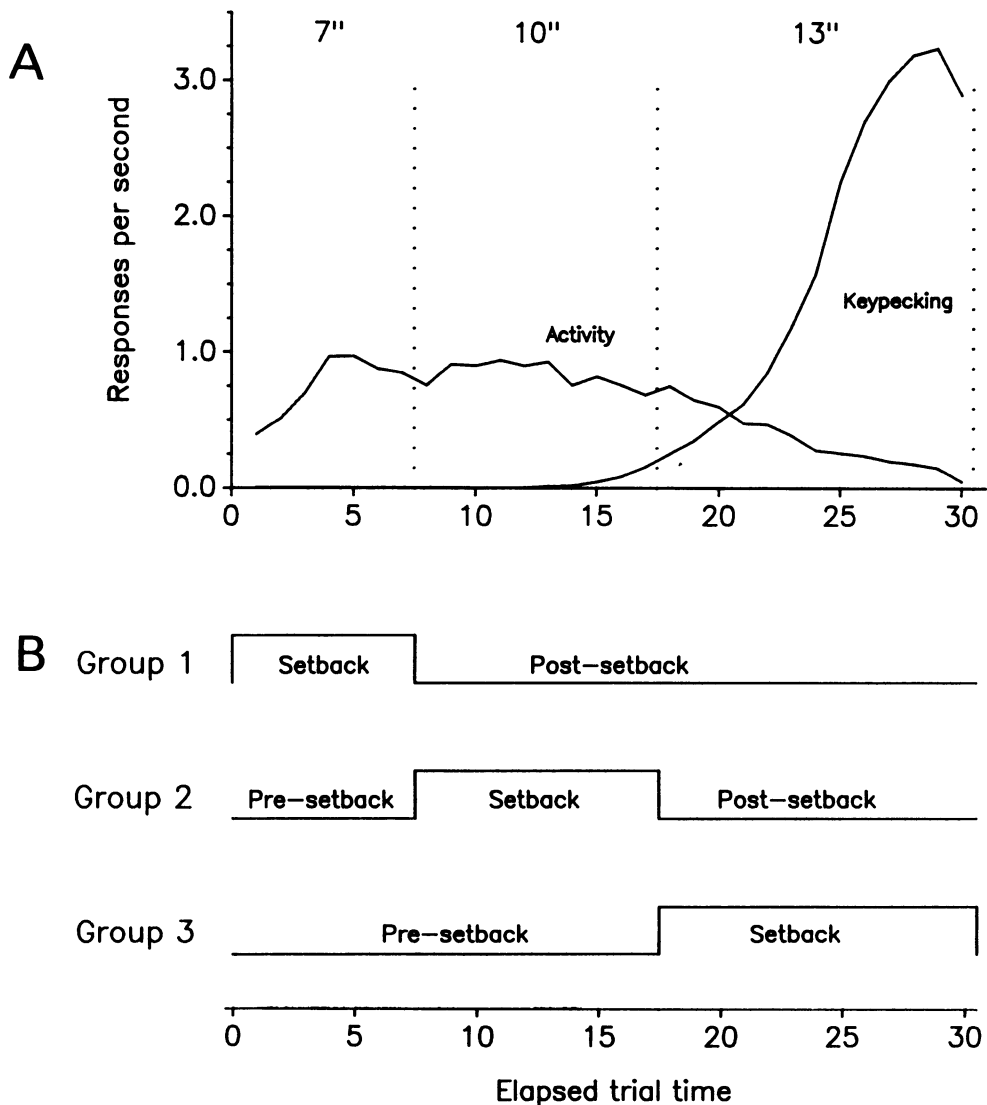
Fig. 3. (A) An intratrial distribution of Phase 1 activity before the setback contingency was put into effect (data taken from the last session of Phase 1, Subject 24). Responses per second are plotted as a function of elapsed trial time. Vertical dotted lines divide activity into three segments, with durations indicated along the top of the figure. Activity and key-pecking distributions are labeled. (B) Schematic diagrams of the conditioning procedures used for each group. Each group diagram shows the relative relationship of setback and pre- and/or postsetback segments as they were scheduled along elapsed trial time. If activity responses were recorded during the setback segment, then the duration of that segment increased as a function of the number of responses.

minal pacing was probable). The initial 17 s of the IRI made up the presetback segment.

*Phase 3.* For five sessions, all subjects in all groups were returned to the no-contingency procedure of Phase 1.

## RESULTS

Detailed records from individual subjects in Groups 1, 2, and 3 are shown in Figures 4, 5, and 6. These figures show activity (upper pan-

els) and key-peck (lower panels) response rates over daily sessions. For each response type, response rates in the segment(s) preceding the setback segment (presetback), the segment(s) following the setback segment (postsetback), and the setback segments are shown separately.

For Group 1 (Figure 4), the setback contingency was imposed during the first segment. The uppermost panel shows the reduction of
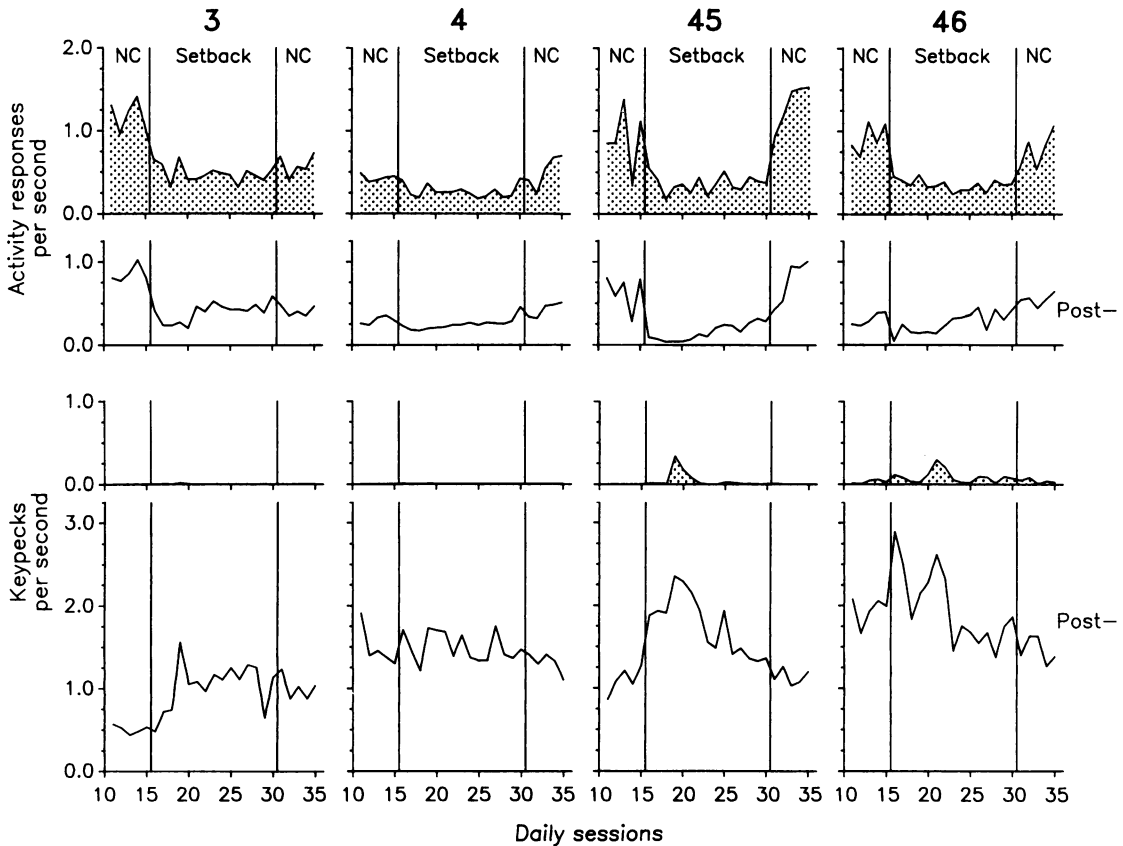
Fig. 4. Activity response rates (upper two rows) and key-pecking response rates (lower two rows) as a function of daily sessions. Labels are similar to those in Figure 2. Separate rows of panels represent setback-contingency segment activity (first row), postsetback activity (second row), setback-contingency segment key pecking (third row), and postsetback key pecking (fourth row). In Figures 4, 5, and 6, the plots of setback-contingency segment behavior are shaded with a dot pattern. Where applicable, pre- and postsetback labels appear to the right of those rows of panels representing performance in those segments.

activity that occurred during the first segment across the sessions of the experiment. During the setback phase, clear activity decreases were evident for Birds 3, 45, and 46, but after removal of the setback contingency, recovery of baseline activity rates was seen only for Birds 45 and 46. The observed response reduction generalized somewhat to postsetback segments, as shown in the second row of panels. Although the overall rates of activity were lower during the postsetback segments, there was clear evidence of an initial activity decrease followed by less conspicuous, gradual recovery across the phase. Bird 4's activity rates were very low before the imposition of the setback contingency, although after the removal of the contingency, activity rates seemed to increase above baseline levels.

Key-pecking rates during the setback con-

tingency for Group 1 were, of course, very low because key pecking did not typically start until well past the first segment. There is an indication, however, that key pecking was enhanced during the postsetback segments, especially for Birds 3 and 45, with Bird 46 showing transient increases in key pecking on selected days. Bird 3's rates of key pecking did not reverse once the contingency was removed in the final phase. Interestingly, these subjects (3, 45, and 46) showed the largest decrement in activity responding during both setback and postsetback segments. For Birds 45 and 46, postsetback increases in key-pecking rates were closely tied to changes in postsetback activity rates. As activity gradually increased over setback sessions, elevated key-pecking rates began to decrease in a mirror-like fashion.

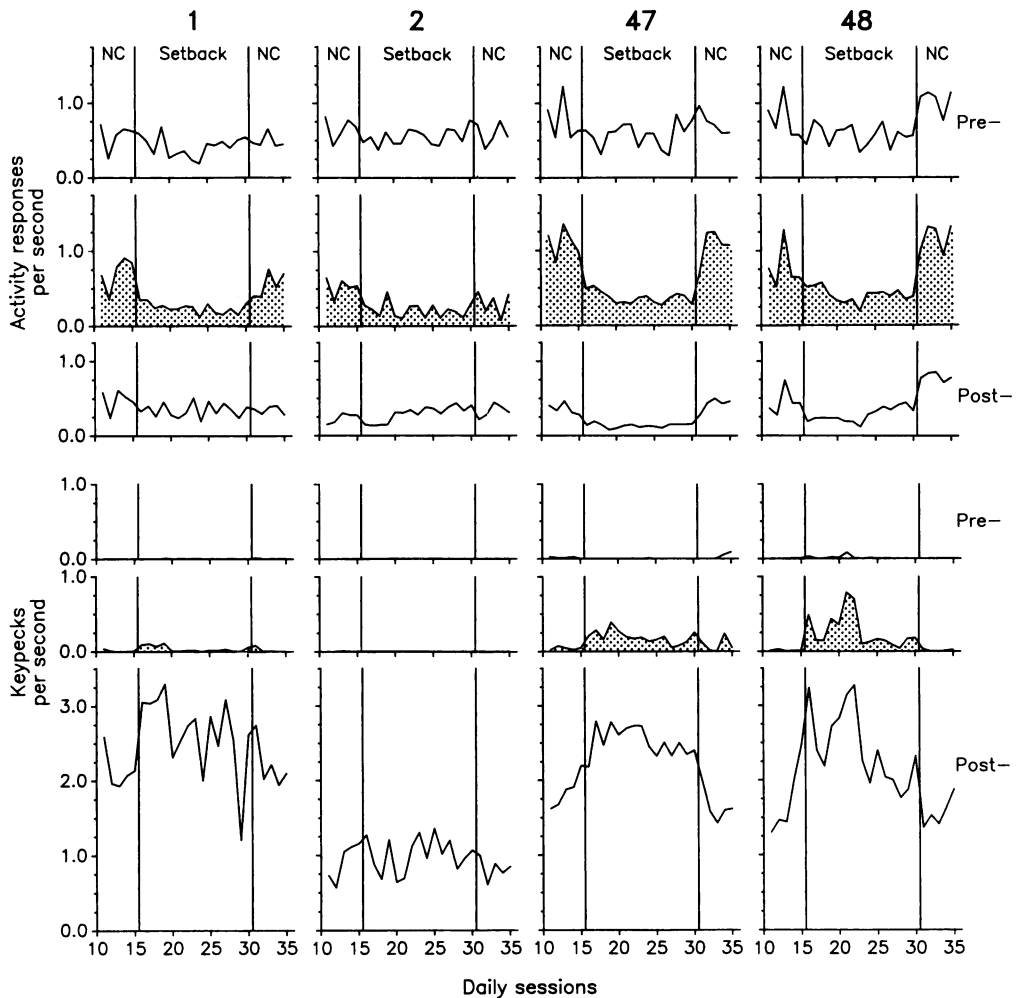Figure 5 shows the effects of the imposition

Fig. 5. Activity response rates (upper three rows) and key-pecking response rates (lower three rows) plotted as a function of daily sessions. Labels and shading are as indicated in Figure 4.

of the setback contingency in the middle segment for Group 2. For each response type (activity and key pecking), the middle row of panels represents the response rates across sessions in the middle segment. The presetback segments are shown in the row above, and the postsetback segments are shown in the row below. Again, reduction of activity during the setback segment was evident during the sessions with the setback contingency. All 4 subjects showed response reduction during this interval, and for 3 birds (1, 47, and 48) there was a clear recovery of responding. There was no indication of response reduction in the presetback segment but, as in Group 1, activity reduction occurred for 2 of 4 birds (47 and 48) during the postsetback segment.

The birds in Group 2 also produced very little key pecking in the presetback segment, presumably because that segment occurred early in the IRI when key pecking was infrequent. However, there was enhanced key pecking during the setback segment for 2 of the 4 birds (47 and 48). In the postsetback segment, when key pecking was normally at its highest level, there was again some indication of an enhancement of rates of pecking for 3 of the 4 birds (1, 47, and 48). It is interesting to note that those birds showing the greatest decreases in activity levels during the setback phase are also those who showed the greatest increase in key-pecking rates during setback and postsetback segments (Birds 1, 47, and 48).
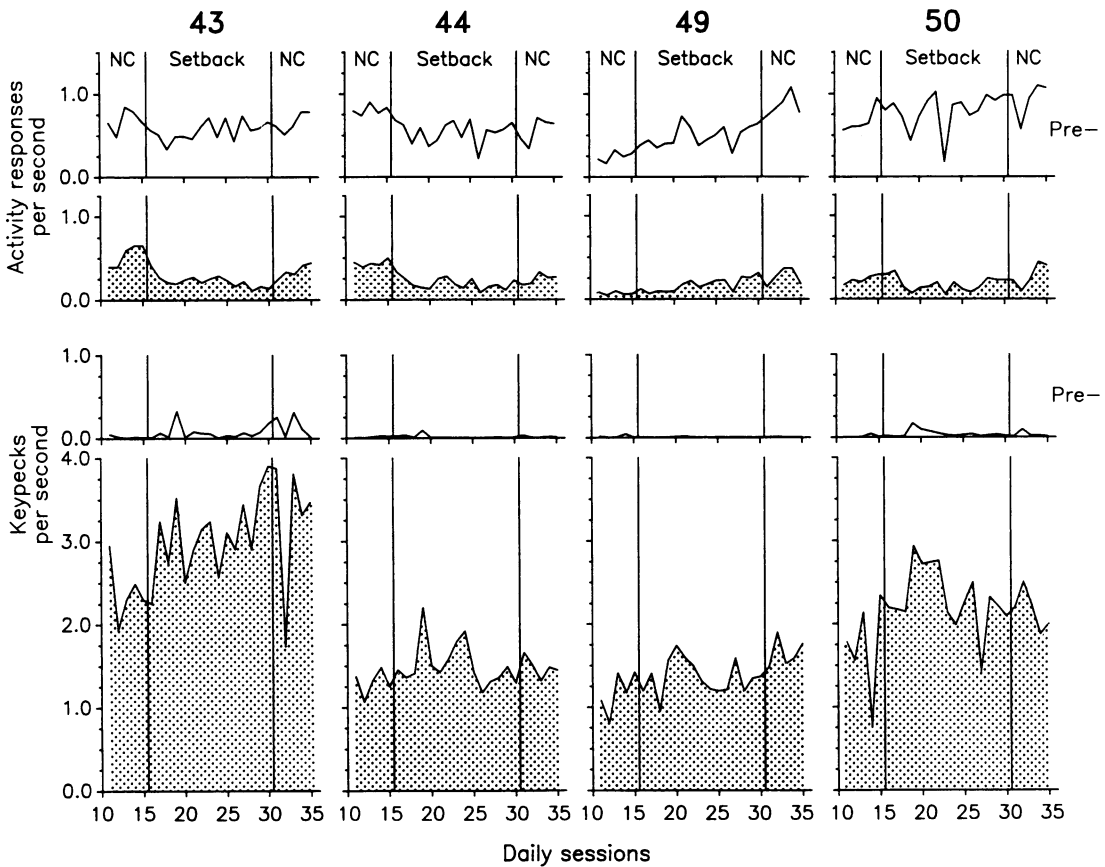
Fig. 6. Activity response rates (upper two rows) and key-pecking response rates (lower two rows) plotted as a function of daily sessions. Labels and shading are as indicated in Figure 4.

For Group 3, the setback contingency was imposed on activity in the last segment (Figure 6). Within the presetback segment, there was little indication of reduction in activity rates during setback sessions. There was some evidence of activity reduction during the setback segment (Birds 43, 44, and 50), but the effect may have been obscured by the low overall rates of terminal pacing that generally occurred in the last segment of the interval when key pecking was very probable.

Key pecking was not systematically affected in the presetback segments. During the setback segment, Phase 2 key-pecking rates were elevated over Phase 1 rates for Birds 43 and 50, with Birds 44 and 49 showing some daily transient increases.

## DISCUSSION

The principal result of this experiment was that an operant contingency imposed on activity (retreat, interim pacing, or terminal pac-

ing) during restricted segments of the IRI selectively reduced activity during those segments. The sensitivity of behavior to this differential contingency demonstrates that schedule-induced activity, like operant behavior, can be differentiated into relatively arbitrary functional response classes.

During the imposition of the setback contingency there appeared to be a discernible enhancement of Phase 2 key-pecking rates that generally accompanied decreased activity rates. If the setback procedure functions to reinforce differentially any behavior other than activity (a DRO schedule; cf. Nevin, 1968), then the observed increased rates of key pecking should consistently follow. However, a DRO contingency does not specify the character or rate of the behavior that eventually supplants the target response, so it is not surprising that some subjects showed increased key-pecking rates but other subjects did not. Although key pecking could certainly compete successfully with

movement about the chamber, pecking is not the only potential competing response. Nevertheless, key pecking and activity were the only responses monitored in the present experiments, so the frequency of other responses that might have entered into a trading relation with activity cannot be specified.

When compared to the more transient increases in key pecking observed in Experiment 1, the increase in key-pecking rates for subjects in Experiment 2 is especially clear. However, it is not clear why the segmented application of the setback contingency generated more systematic increases in key pecking. One possible interpretation is that when the setback contingency is in effect throughout the IRI, locomotor responses will alter any or all of the stimuli presented. This response-dependent stimulus change may actually result in a ragged stimulus sequence that will be less likely to support key pecking (cf. Matthews et al., 1990). When the setback contingency was arranged during smaller portions of the IRI, most of the stimulus values remained unaffected by locomotor responding. Consequently, once the setback segment was over, the remainder of the stimulus sequence was unaffected by responding, thereby allowing for continued control of key pecking. However, this explanation of selective key-peck modulation as a function of activity decrease is less satisfying when one considers the fact that activity rates were so low for all subjects that the average IRI went from 30 s to approximately 35 to 37 s in duration. This means that, on average, only five to seven of the stimuli in the 30-stimulus sequence were altered by activity responses, with most of the alteration occurring during the first half of the IRI. It is clear that further work must examine the effects of using a contingency during only a portion of the IRI.

Finally, the increase in key pecking associated with the decrease in activity may be a reflection of a weakening of precise signal control over pecking rather than a competitive increase in pecking replacing the reduction in activity. This notion of response competition will be discussed more thoroughly below.

## GENERAL DISCUSSION

These experiments have demonstrated the capacity of the setback contingency to reduce the frequency of schedule-induced behavior. Contingent decrease of terminal key pecking

(Allan & Matthews, 1991) and schedule-induced drinking (Pellon & Blackman, 1987) have been previously described, but the present results provide strong evidence that schedule-induced locomotor activity is also sensitive to its consequences. The decrease in activity was rapidly acquired, was sustained throughout the contingency period (at levels well below those required to allow continued food delivery, i.e., anything less than one response per second), and activity generally recovered quickly once the contingency was removed.

Why the setback contingency is so effective in reducing the frequency of a target response remains an open question. Allan and Matthews (1991) speculated that individual stimulus changes might function either to (a) reinforce adventitiously alternate competing responses (an explicit DRO contingency; Nevin, 1968) or (b) serve as secondary or conditioned punishers of responses that immediately produce stimuli correlated with increased time to the next reinforcer (see Auge, 1977). Optimal use and understanding of the setback contingency will come from a clear functional analysis of these contingency parameters.

The increase in key pecking observed in these experiments might be interpreted as evidence of a competitive relation between activity and key pecking (Staddon, 1977). However, that possibility is diminished by the lack of systematic and generally sustained increases in key pecking in Experiment 1. If key pecking and activity were competing with each other for expression, then the dramatic reduction in activity rates observed in Experiment 1 should have been accompanied by a conspicuous, systematic increase in key pecking. This finding of a putative competing relation between activity and key pecking (particularly in Experiment 2) resembles the results of previous work involving either the injection of tranquilizing drugs or the narrowing of the range over which light-intensity values changed during the ramp stimulus. Both of these procedures resulted in decreased activity and increased key pecking (Bordi & Matthews, 1990). As mentioned earlier, these trading relations may be a function of a weakening of the precise stimulus control established during sessions with response-independent food presentations. Nevertheless, the question of why this collection of procedures (Bordi & Matthews, 1990, and Experiment 2 of the present work) results in a trading relation between activity and key pecking is not

clear, and further research must address this issue.

Although several birds' rates of key pecking did increase as their activity rates decreased in Experiment 2, nothing short of an explanation of response sensitivity based on response–consequence dependencies will suffice in these experiments. Although it is true that changes in density of reinforcement and stimulus intensity values both were contingent on responding, these alterations in scheduled events alone cannot explain why the frequency of the target behavior was reduced. Similar density of reinforcement and stimulus changes have been produced when key pecking was the target response (Allan & Matthews, 1991) and yet, in all cases, only the rate of the target response was *reduced*; the "competing" response either remained unaffected (Allan & Matthews, 1991) or *increased* in frequency (e.g., Experiment 2). If change in reinforcer density was the source of response reduction, then all responses should be correspondingly reduced.

Experiment 2 further showed that the operant sensitivity of activity did not vary with the position of the behavior in the IRI. The near uniformity of operant sensitivity of schedule-induced activity across the IRI may be surprising in light of the many distinctions that have been drawn among schedule-induced interim activities. Cohen and Campagnoni (1989) have shown that elements of interim activities may be differentially sensitive to IRI duration, and Gibbon (1977) has suggested that some interim behavior may be a true postreinforcement effect rather than tied to the coming reinforcer, the implication being that some interim responding should be relatively insensitive to its consequences. Matthews et al. (1990) have shown that interim retreat, which tends to follow the withdrawal of the reinforcer, may, in fact, have more in common with terminal key pecking than with interim pacing, which tends to occur in the midportion of the IRI. Again, despite these divisions among schedule-induced interim behavior, there was no evidence here that movement responses, regardless of their temporal position with respect to reinforcement, differed in their sensitivity to operant contingencies.

Although the effectiveness of operant contingencies does not seem to vary with the type of schedule-induced behavior upon which it is imposed, it is nevertheless true that operant contingencies are capable of effectively differentiating separate operant classes among ongoing schedule-induced behavior. In Experiment 1, the setback contingency reduced the target behavior—activity—but had little systematic effect on key pecking. In Experiment 2, the setback contingency was imposed on behavior occurring in restricted segments of the IRI and the contingency differentially reduced activity during those target segments. Previous work (Allan & Matthews, 1991) has shown that when key pecking was the target behavior, it was contingently reduced by the setback contingency. Thus, whether divided by form (activity or key pecking) or temporal distribution, all behavior responded selectively to differential operant contingencies.

The present results suggest that operant contingencies can work independently of the schedule factors that originally induced and differentiated behavior into distinctive descriptive classes of interim and terminal behavior. Indeed, a Pavlovian conditioned stimulus signaling a reinforcer may divide behavior into one set of classes, and operant contingencies may divide the same behavior stream into a different set of functional classes. This independence of Pavlovian and operant influences on behavior seems to broaden the power of each process, thereby limiting the constraints these processes impose on each other.

Of course, it would certainly be conceptually simpler if schedule-induced behavior was exclusively sensitive to the temporal patterns of stimulus and reinforcer delivery and if operants were exclusively sensitive to their consequences. The demonstrated failure of this functional isolation of response classes will add to the challenge of identifying underlying mechanisms of behavior control.

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